Demand Access System (DAS)

Special Topic:
DAS Scheduling Algorithm

21 March 2001

Updated: 27 March 2001

ITT Industries
Engineered for life

Outline

- **Nominal (Re)Planning: Planning Prior to Service**

Emergency Replanning: Planning During Service

Future Enhancements

Odd WSGT IBUG Optimization (Backup Only)

Key Elements of the Scheduling Algorithm

- **Schedules consists of 24 hour daily segments (0000 to 2400)**
- **Schedules are first generated daily at 0000, 4 days (96 hrs) in advance**
- **Schedules can be 'replanned' at any time prior and during service**
  - Nominal Replanning: replanning prior to service
  - Emergency Replanning: replanning during service
- **Scheduling consists of various tables that completely capture the schedule for each day - new table for each new day**
- **In general, only five days worth of tables are required**
- **It is anticipated that a 24 hr schedule can be generated or replanned within minutes, if not less**

Key Design Assumptions

- Planning and schedules are generated and viewed on a day by day basis; this is a '5-day sliding window' rather than a sliding window of a 96 hours segment

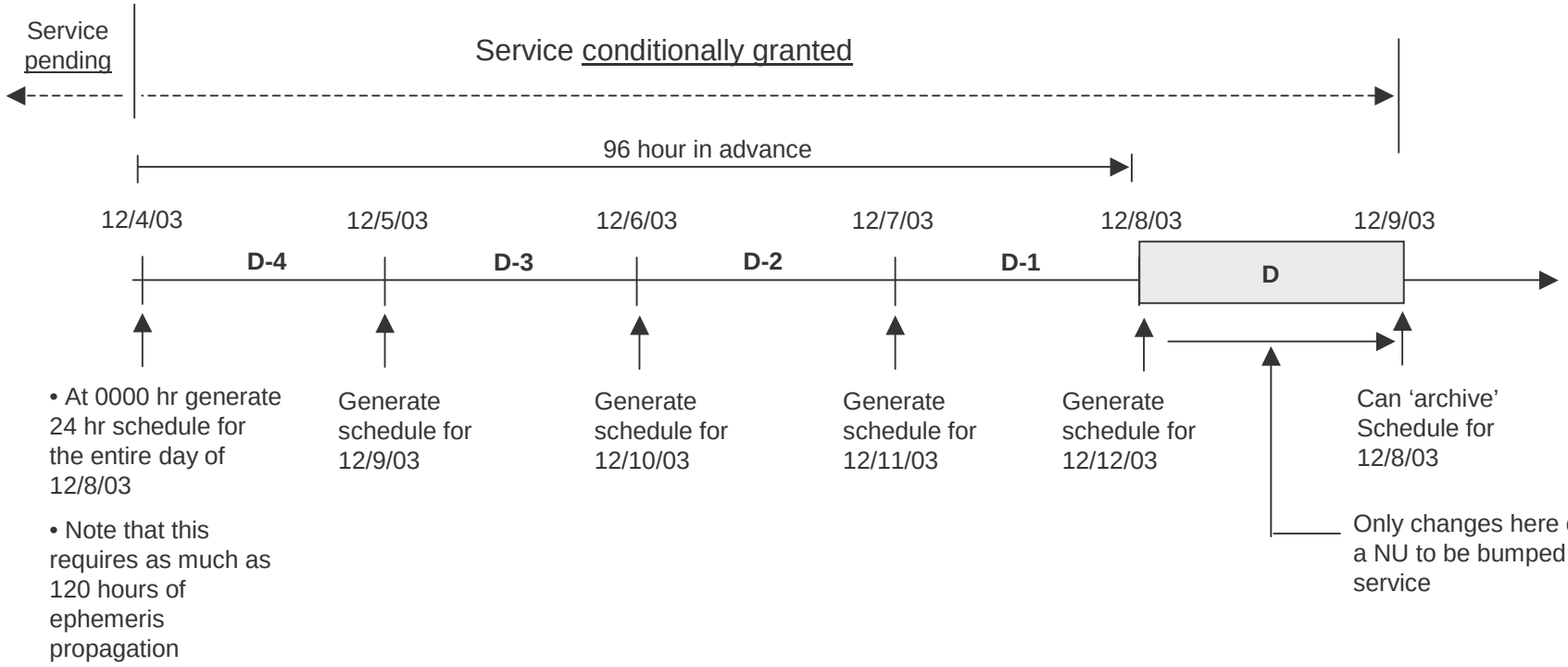
- Customers who want more than single TDRS coverage must submit a separate service request for each TDRS. This constraint is driven by UPD delivery via NISN and not by the Scheduler
- Formation Flyers must submit a separate service request for each platform with the exactly the same start and finish times. The Scheduler looks for common SIC group (set in Database) and service times to assign multiple DMUs to a single IBU
- Dedicated stationary 24x7 users are supported with the same IBU/DMU combination from day to day to avoid breaking active links. Nondedicated stationary 24x7 users are supported with the same IBU/DMU combination from day to day to avoid breaking active links unless they get 'bumped' by a dedicated user requiring those resources.

- Users who are rejected at any point within the 5-day planning window, automatically remain in the queue and are reassessed each time conditions change (SV updates, deleted services, equipment availability updates, etc.)

Key Simplifying Assumptions

- **Odd IBUG at WSGT "pre-selected" to cover either TDE or TDW**
  - Scheduler does not make assignment
  - An odd IBUG at WSGT would support either TDW or TDE with only 'static' selection via database modification

Illustrative Scheduling Timeline
(For Day beginning 12/4/03)



Replanning Possible for 12/8/03 Daily Schedule

- Replanning can occur at any time
- Due to: new services, new state vector, deleted services, failed IBUs and DMUs
- At any given time there are 5 separate daily schedules
- Replanning requires updating possibly up to 5 daily schedules

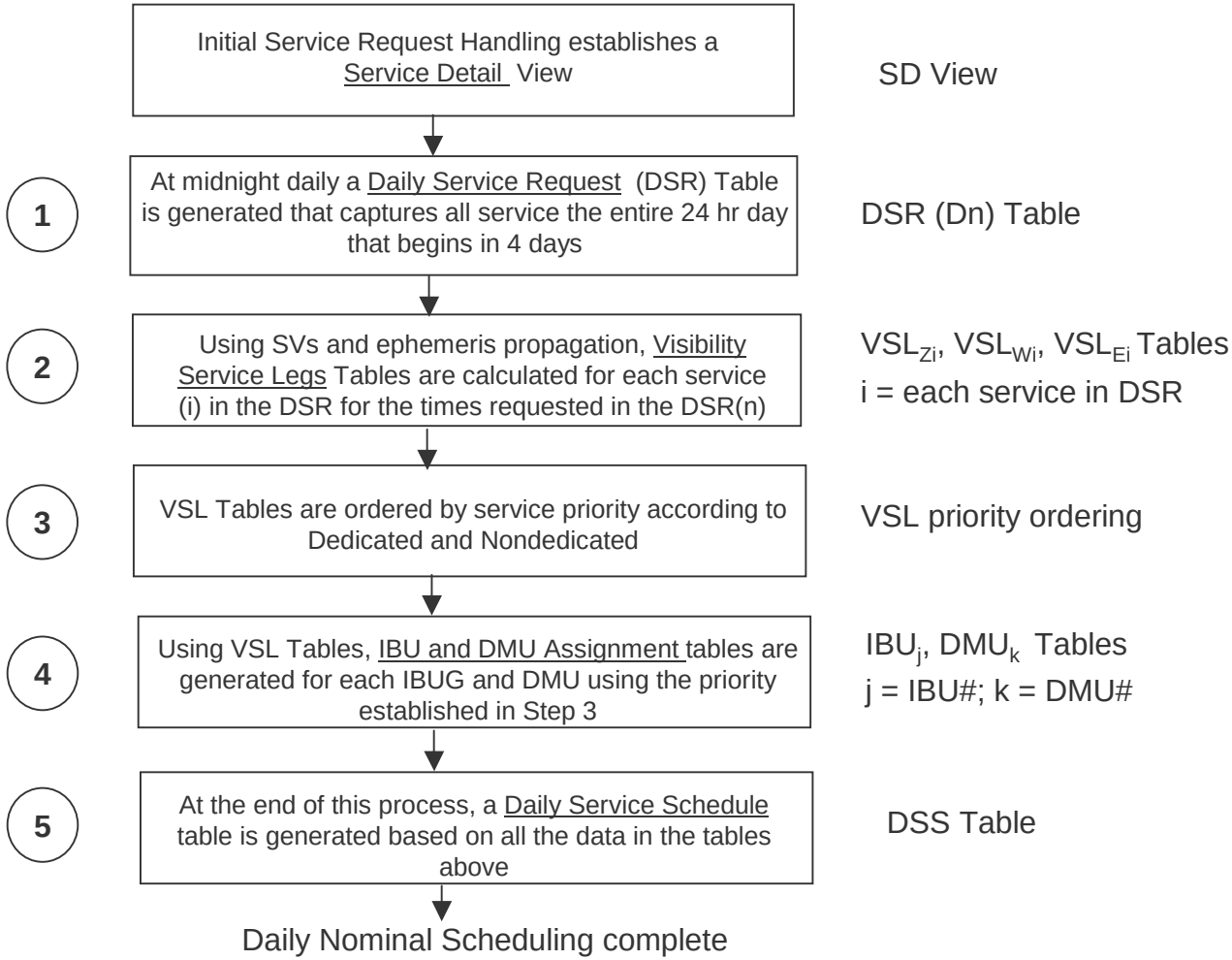
Approach Overview
(Based on Daily Tables)

'Nominal' Planning	'Nominal' Replanning	'Nominal' Replanning	'Nominal' Replanning	'Emergency' Replanning
Day D-4	Day D-3	Day D-2	Day D-1	Current Day D

• **DSR**: Daily Service Request Table
  • One Table Only
• **VSL**: Visibility Service Leg Tables
  • One table for TDRS
• **IBU**: IBU Assignment Tables
  • One table for each IBU
• **DMU**: DMU Assignment Tables
  • One table for each DMU
• **DSS**: Daily Service Schedule
  • One Table Only				

- **Scheduling approach consists of maintaining 5 days of 'daily' tables**
- **Services are subdivided into TDRS 'Visibility Service Legs' and assigned to equipment on this basis**

Nominal Daily Scheduling & Resource Assignment



Scheduling/Resource Overview
Nominal

- **Future Scheduling/Resource-Allocation perform once per day**
  - Say at 0000 hr each day, say Day Dn
  - All Services scheduled to begin in the day Dn+4 =96 hrs in the future are are assessed and allocated to IBUs and DMUs
- **Order of assignment**
  - Dedicated User continued from previous day (CDU)
  - *Non-Dedicated User continued from previous day (CNU)*
  - New Dedicated User (NDU); *can bump a CNU if needed, but want to avoid this if possible*
  - *New Non-Dedicated User (NNU)*
- **Services allocated to IBUs/DMUs in terms of "Visibility Service Legs"**
- **Daily schedule consists of services mapped by service legs to IBUs and DMUs**
- **Users that cannot be assigned to one or more requested legs are kept in the request schedule and reassessed each time the schedule is replanned**
- **Notation**
  - Service ID: xxxxxxx
  - SIC Code: yyy
  - Visibility Service Leg ID: zzz

Service Detail View, SDV (0000-2400)

SDV

Request Time	Service ID	User SIC	Start Time	Finish Time	DU or NU	TDRS
SDV_i →	xxxxxxx	yyy	T_{S3}	T_{F3}		
	xxxxxxx	yyy	T_{S2}	T_{F2}		
	xxxxxxx	yyy	T_{S1}	T_{F1}		

0: Best TDRS
1:TDW
2:TDW^{I}
3:TDE
4:TDE^{I}
5:TDZ
6:TDZ^{I}

Services are scheduled on a day by day basis

- Will refer to any particular row as a 'service' or 'user'
- Index ' i ' refers to one entire service or a single row in the SDV

- This table is set up from DASCON Service Initial Request Process as input to the scheduling algorithm
- Not a 'daily' table

Daily Service Request Table, DSR(Dn)

DSR(Dn) Table

Request Time	Service ID	User SIC	Start Time	Finish Time	DU or NU	TDRS	Multiple DMUs	'Continued'
	xxxxxxx	yyy	T_{S3}	T_{F3}				Yes
	xxxxxxx	yyy	T_{S2}	T_{F2}				Yes
	xxxxxxx	yyy	T_{S1}	T_{F1}				No

Includes all services from SDV that are requested in Day Dn

- Dual Channel QPSK
- Formation Flyers

$DSR_i(Dn)$ — i th service or row in day Dn

- This table is set up from DASCON Service Detail View each day
- Each Day D_n at 0000 hr, all services that have T_{si}'s that occur anywhere in day D_{n+3} are processed
- Services from the previous day scheduled that were not finished at 2400 on Day Dn-1 are considered 'continued' and will have priority when resource assignments begin (TBR)
- Request Time determines priority within DU and NU

Visibility Service Leg Tables, VSL_Z, VSL_W, VSL_E

VSL_Z Table

Service ID	User SIC	Start Time	Finish Time	Leg ID #
xxxxxxx	yyy	T_{S3}	T_{F3}	zzz
xxxxxxx	yyy	T_{S2}	T_{F2}	zzz
xxxxxxx	yyy	T_{S1}	T_{F1}	zzz

VSL_W Table

VSL_E Table

Notes:

- Indicates visibility from each TDRS to User
- Z,E,W corresponds to TDZ, TDE, TDW – *5 tables if multiple TDRSs per node*
- Used to determine IBU/DMU allocations
- Can be generated upon receiving a new SV update or 96 hrs prior to service start
- 'Leg IDs' are generated as part of this process

- These Tables are based on Nodes for 'TDRS' Parameter ≠ 0 (I.e., best TDRS)
- ≠

Daily IBU Assignment Tables, IBU_j

IBU_j Table (for each IBU)

Start Time	Finish Time	User Type	Service ID #	Leg ID#
1 - 3				
T_{S3}	T_{F3}	DU	xxxxxxx	zzz
T_{S2}	T_{F2}	NU	xxxxxxx	zzz
T_{S1}	T_{F1}	NU	xxxxxxx	zzz

- 1-3 Indicating to which TDRS it is assigned
- Use -1 to indicate not available
- May need 1-5 if need to account for multiple TDRSs per node

Notes:

- j index = IBUs
- 1,2,3 corresponds to TDZ, TDW, TDE and are fixed to a specific TDRS – *5 tables if multiple TDRSs per node*
- Note that all IBUs within the same IBUG all have the same 'TDRS' connectivity

- Service Leg – a resource allocation that spans a single TDRS visibility window
- A service can be composed of many service legs
- Time spans above are essentially 'service legs'

Daily DMU Assignment Tables, DMU_k

DMU_k Table (for each DMU)

Start Time	Finish Time	User Type	Service ID #	Leg ID#
1- 2				
T_{S3}	T_{F3}	DU	xxxxxxx	zzz
T_{S2}	T_{F2}	NU	xxxxxxx	zzz
T_{S1}	T_{F1}	NU	xxxxxxx	zzz

- 1-2 Indicating to which GT it is assigned
- Use -1 to indicate not available

Notes:

- k index = DMUs
- 1 corresponds to GRGT
- 2 refers to WSC (can support either TDE or TDW)
- Use 'Dual Channel' in DSR table to assign multiple DMUs to the same VSL ID#

Daily Service Schedule Table, DSS (Dn)

DSS (Dn) Table ; Day Dn

Repeated for each leg scheduled and assigned to each service

Service ID #	User SIC #	User Type	Leg ID #						
			Leg ID	Start Time	Finish Time	IBU # j	DMU # k	Rejected	
yyy	xxxxxxx	NU	zzz	T_{S3}	T_{F3}				
yyy	xxxxxxx	NU	zzz	T_{S2}	T_{F2}				
yyy	xxxxxxx	NU	zzz	T_{S1}	T_{F1}				
yyy	xxxxxxx	DU	zzz	T_{S1}	T_{F1}				

DSS_i

. . .

Notes:

- Represents all services in the queue requesting service for Day n
- Services divided into legs with corresponding DMU and IBU assignments
- ND users are rejected on a 'leg-by-leg' basis

Legs that have Finish Times T_F at 2400 hrs are considered 'continued' (or can just leave T_F blank or -1 or 2400)

IBU/DMU 'Cycling'

- Want to ensure that IBUs/DMUs are allocated equally over time
- Use an IBU/DMU counter to start looking for available time in a different IBU/DMU each time service is planned/replanned
- Denote as "IBU_Counter" and "DMU_Counter"
- This Cycling approach is bypassed for 'continued' services to avoid breaking links unnecessarily
- As a future enhancement can accommodate cycling for 24x7 users as well
- May need to dismiss 24x7 non-dedicated users as 'continued' every day, otherwise they get service priority over all other non-dedicated users

Generate DSR from DSV

1 (See Slide 7)

DSV

Input

Extract all Services in DSV that have Start Time T_S in Day Dn+3 or have been marked as 'Continued'; this is very straightforward by essentially using only three columns of the DSV

Output

Request Time	Service ID	User SIC	Start Time	Finish Time	User Type	Dual Channel	'Continued'
	xxxxxxx	yyy	T_{S3}	T_{F3}			Yes
	xxxxxxx	yyy	T_{S2}	T_{F2}			Yes
	xxxxxxx	yyy	T_{S1}	T_{F1}			No

Daily Service Request Table DSR

Generate VSLs from DSR

2

- User Service Times: T_{Si} - T_{fi}
- User SV

Input (DSR Table)

Generate Ephemeris Data using latest SV up to Time T_{Fi}

Specific TDRS Requested

- Generate visibility times between T_{Si} - T_{fi}
- Do not consider best look angles; just use total visibility for Requested TDRS(s)

No Specific TDRS Requested

- Generate visibility times between T_{Si} - T_{fi} based on best look angles

Output

VSL_Z

Service ID	User SIC	Start Time	Finish Time	Leg ID #
		T_{S3}	T_{F3}	zzz
		T_{S2}	T_{F2}	zzz
		T_{S1}	T_{F1}	zzz

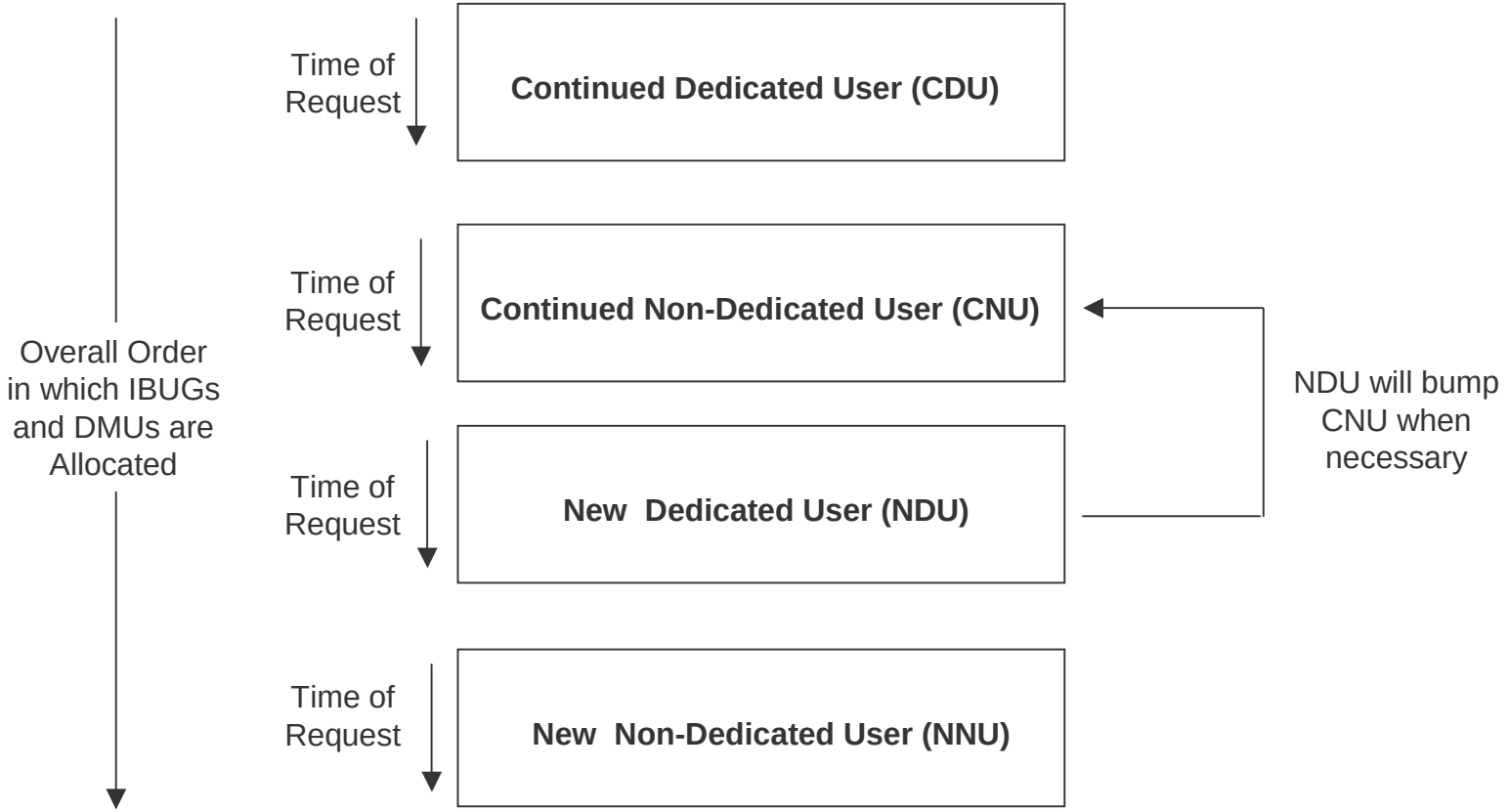
VSL_W

VSL_E

Please see slide 45 for simplifying assumptions if DAS is to support multiple TDRSs per node.

Assignment Order of VSL Tables in IBU/DMU Allocation

3

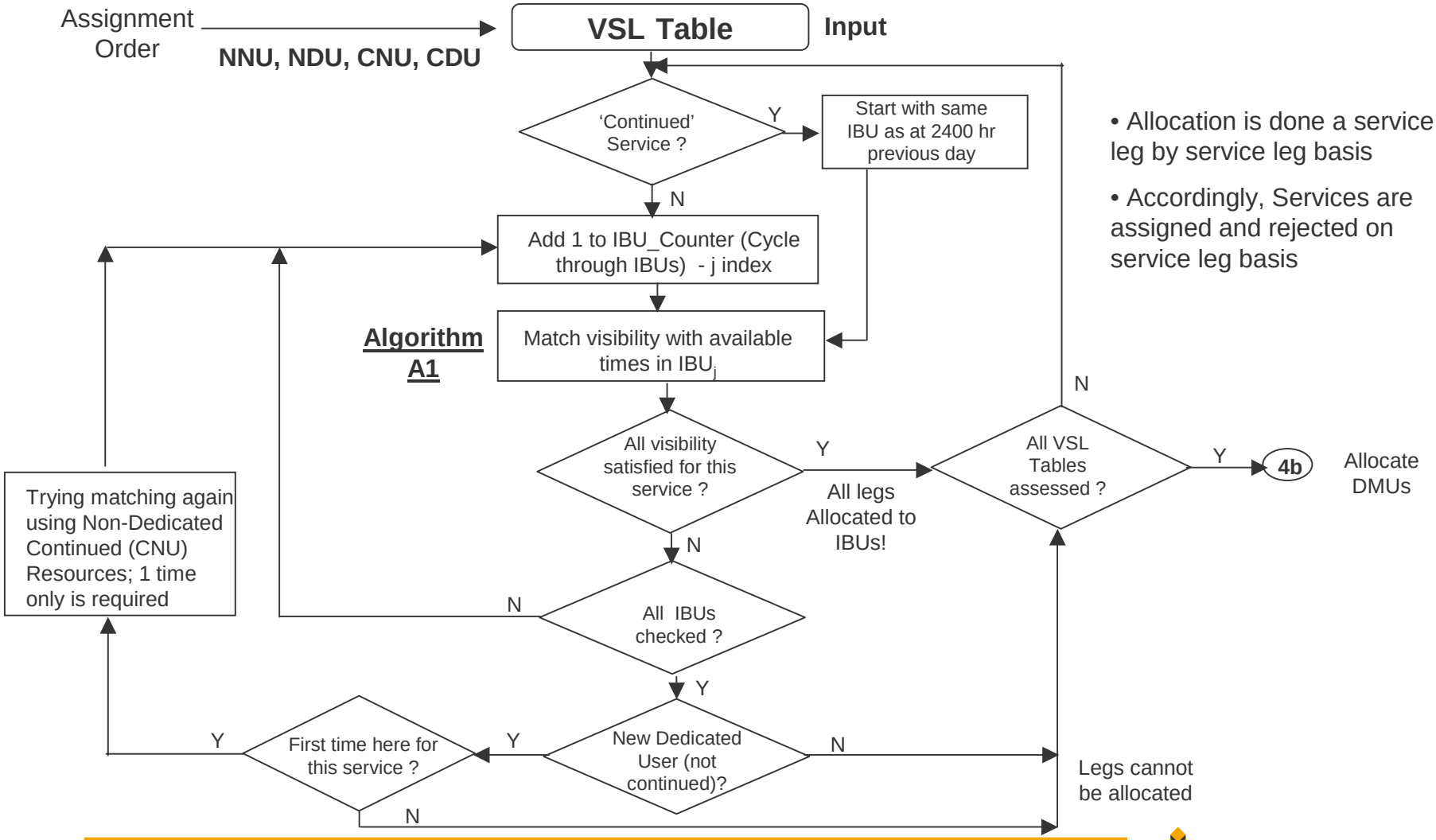


- 'Time of Request' is the time at which the request for service was made
- Thus, customers are assigned on a 'first-come, first-serve' basis

Generate IBU$_j$s from VSLs

4a

Allocate Visibility Service Legs to IBUs



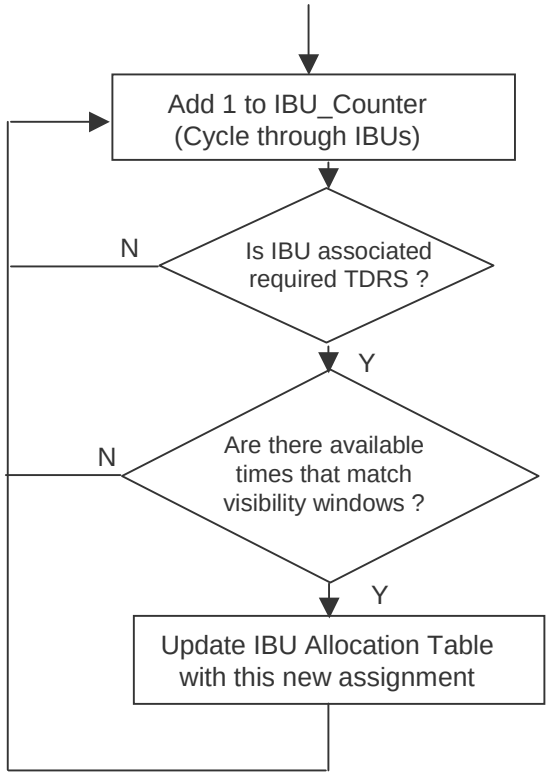
- Allocation is done a service leg by service leg basis
- Accordingly, Services are assigned and rejected on service leg basis

Algorithm A1
IBU Allocation Tables

IBU_j (for each IBU)

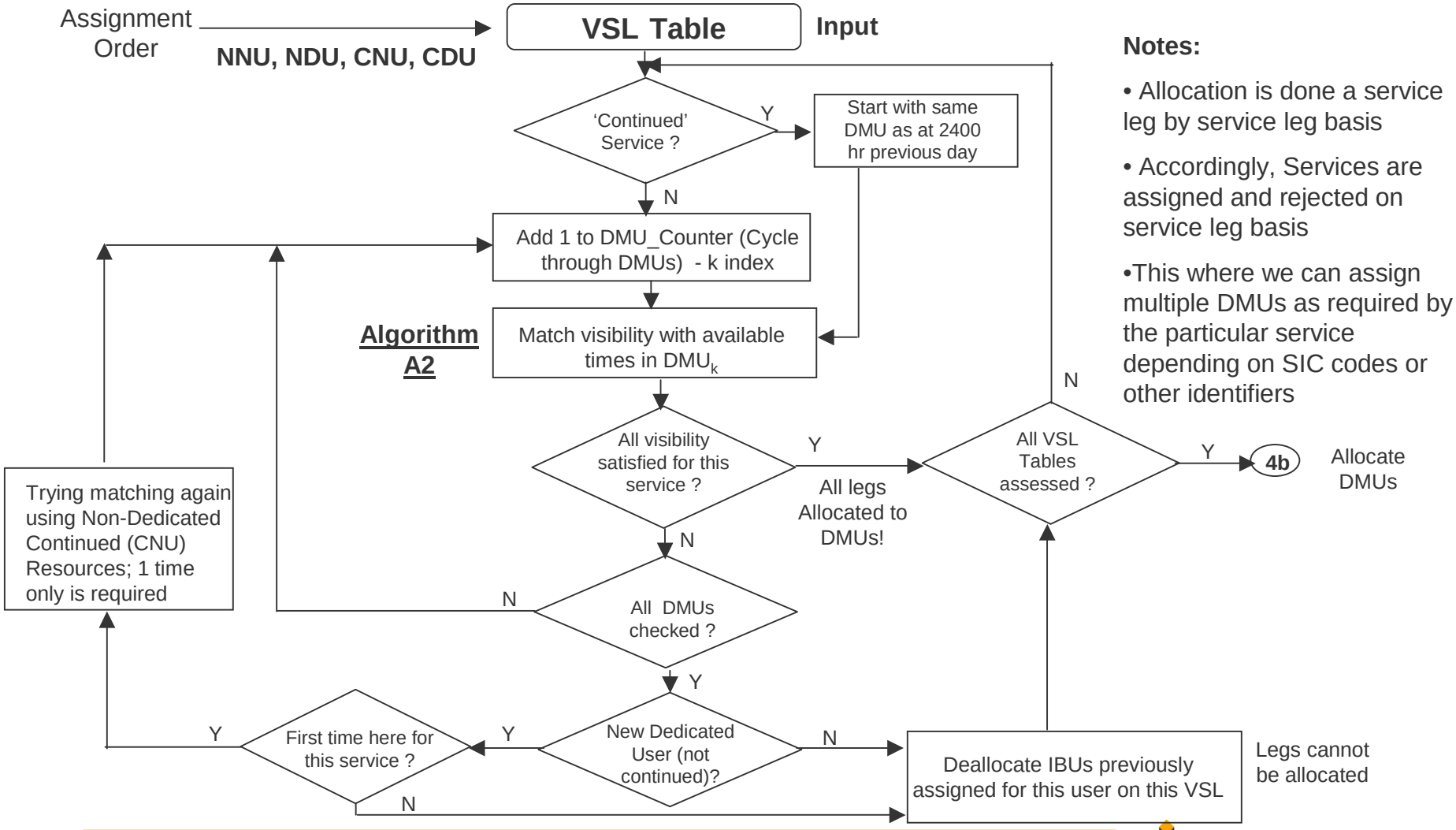
Start Time	Finish Time	User Type	Service ID #	Leg ID#
1 - 5				
T_{S3}	T_{F3}	DU	xxxxxxx	zzz
T_{S2}	T_{F2}	NU	xxxxxxx	zzz
T_{S1}	T_{F1}	NU	xxxxxxx	zzz

VSL Table



Generate DMU_ks from VSLs (4b)

Allocate Visibility Service Legs to DMUs



Notes:

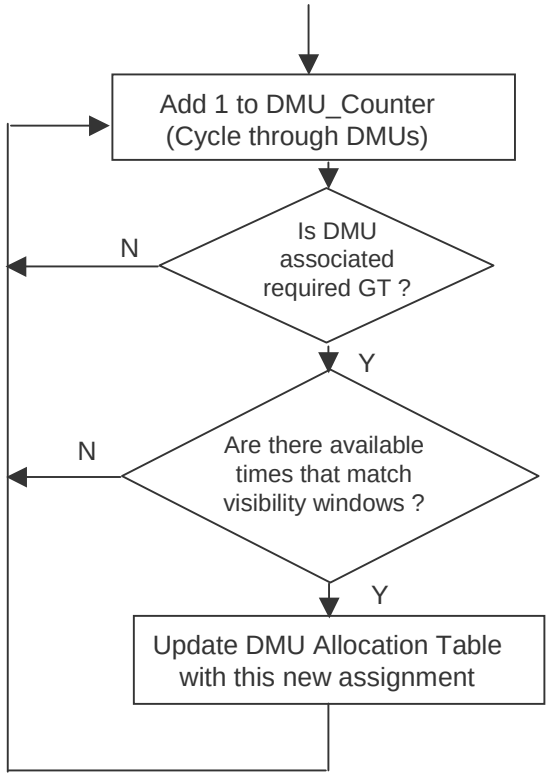
- Allocation is done a service leg by service leg basis
- Accordingly, Services are assigned and rejected on service leg basis
- This where we can assign multiple DMUs as required by the particular service depending on SIC codes or other identifiers

Algorithm A2
DMU Allocation Tables

DMU_k (for each DMU)

Start Time	Finish Time	User Type	Service ID #	Leg ID#
1- 2				
T_{S3}	T_{F3}	DU	xxxxxxx	zzz
T_{S2}	T_{F2}	NU	xxxxxxx	zzz
T_{S1}	T_{F1}	NU	xxxxxxx	zzz

VSL Table



Generate DSS Table (Daily Service Schedule)

5

DSR
IBU_j
DMU_k

Input Tables

DSS (Dn) ; Day Dn

Service ID #	User SIC #	User Type	Service Leg 1 →					
			Leg ID	Start Time	Finish Time	IBU #	DMU #	Rejected
yyy	xxxxxxx		zzz	T_{S3}	T_{F3}			
yyy	xxxxxxx		zzz	T_{S2}	T_{F2}			
yyy	xxxxxxx		zzz	T_{S1}	T_{F1}			
yyy	xxxxxxx		zzz	T_{S1}	T_{F1}			

. . .

Continues for each service leg of each service

Initial ROM Sizing for a Planning Session

- **LEO User (90 minutes orbit)**
  - 24 hour ephemeris processing
  - Visibility Service Legs ~ 3 x (24*60/90) = 48 legs

- **Times the number of users**
  - Final Maximum: 100 users → 4800 legs
  - Initial Maximum: ~10 users → 480 legs

- **Note that processing is basically linear with little or no optimization required through any recursive techniques**

Outline

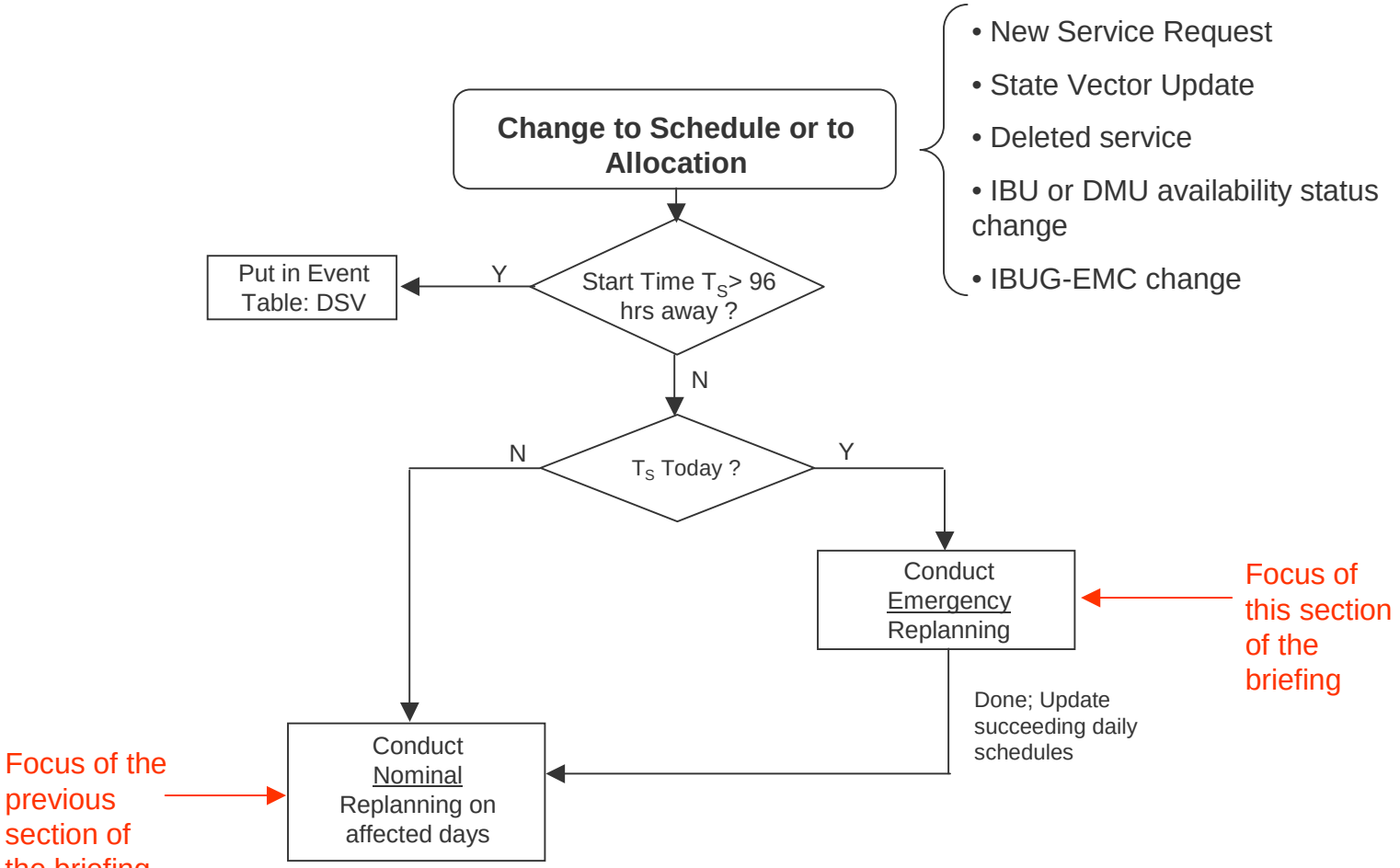
Nominal (Re)Planning: Planning Prior to Service

Emergency Replanning: Planning During Service

Future Enhancements

Odd WSGT IBUG Optimization (Backup Only)

Schedule/Allocation Change



Emergency Replanning (1 of 2)
(i.e., Replanning During Service)

- **Category 1: New Service**
  - Generate VSLs, IBU_j, DMU_k, new DSS
  - *May 'bump' non-dedicated users on certain legs if new user is a DU*

- **Category 2: New User State Vector**
  - Delete all legs form IBU_j, DMU_k associated with this service; then becomes Cat 1
  - Generate VSLs, IBU_j, DMU_k, new DSS
  - *May 'bump' non-dedicated users on certain legs*

- **Category 3: Deleted Service**
  - Delete all legs form IBU_j, DMU_k associated with this service (Similar to 1st step of Cat 2)
  - Try to reassign previously rejected services using new resources
  - No changes to any other service

- **Category 4: New available IBU or DMU**
  - Try to reassign previously rejected services using new resources (Similar to 2nd part of Cat 3)
  - No changes to services that are currently assigned

Emergency Replanning (2 of 2)
(i.e., Replanning During Service)

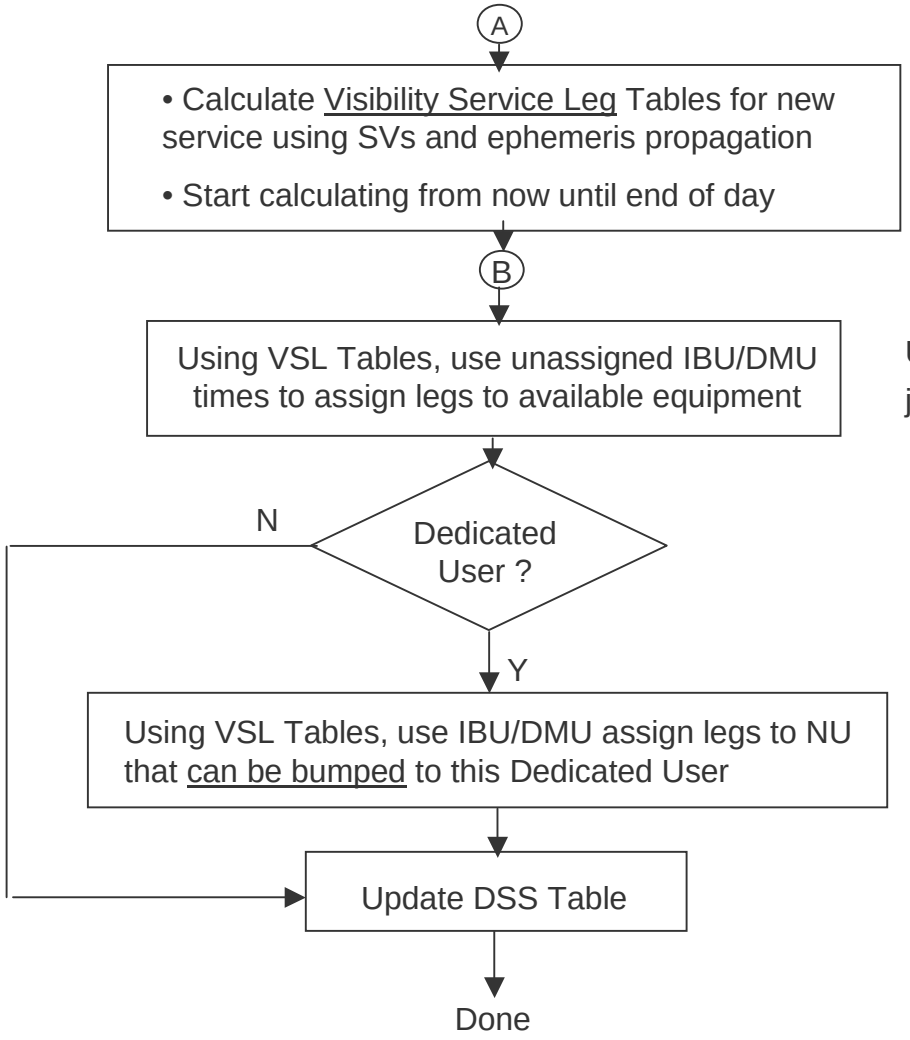
- **Category 5: Failed IBUs or DMUs**
  - First: Reassign DUs using available IBUs or DMUs and then those assigned to NUs
  - Second: Reassign NUs using available IBUs or DMUs (cannot bump anybody else - DUs or NUs)

- **Category 6: IBUG reassignment to different TDRS**
  - Perform total replan of all *legs on all affected TDRSs*

- **Category 7: New TDRS State Vector**
  - Delete all legs form IBU_j, DMU_k associated with this TDRS; then becomes Cat 1
  - Generate VSLs, IBU_j, DMU_k, new DSS
  - *May 'bump' non-dedicated users on certain legs*

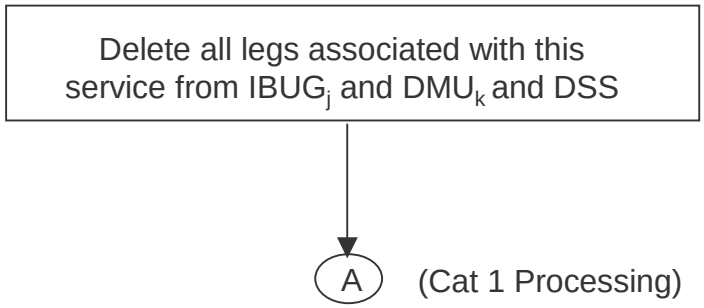
Emergency Replanning - Category 1

New Service

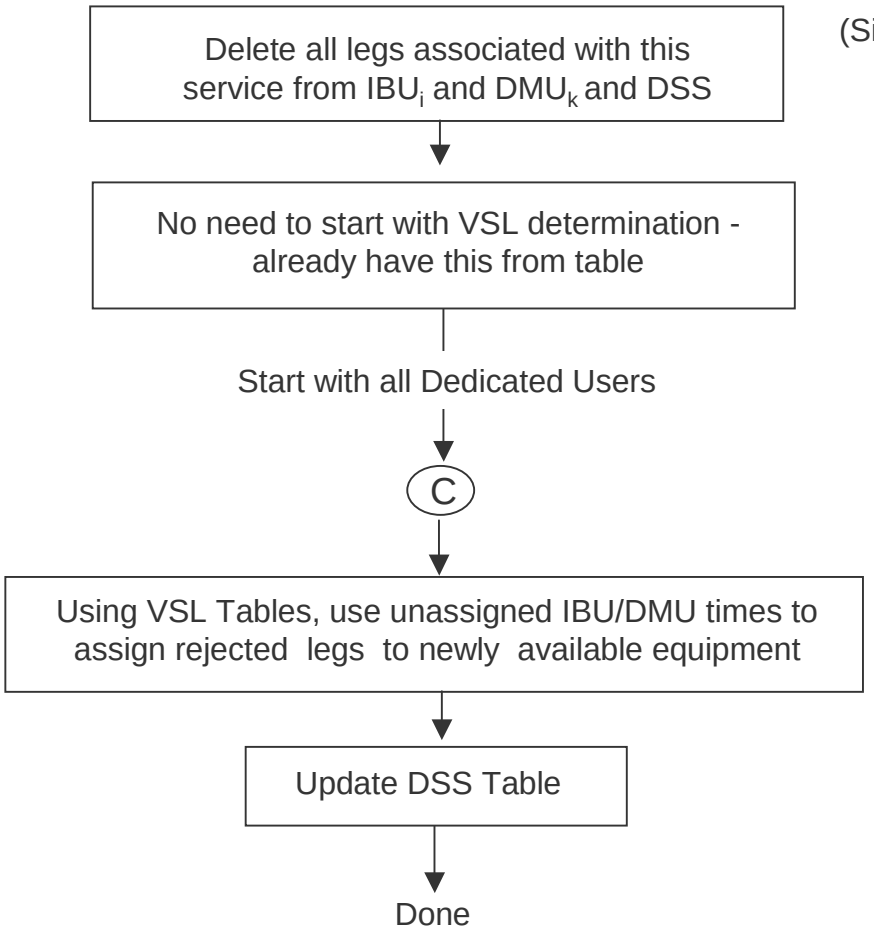


Emergency Replanning - Category 2

New User State Vector



Emergency Replanning - Category 3
Deleted Service

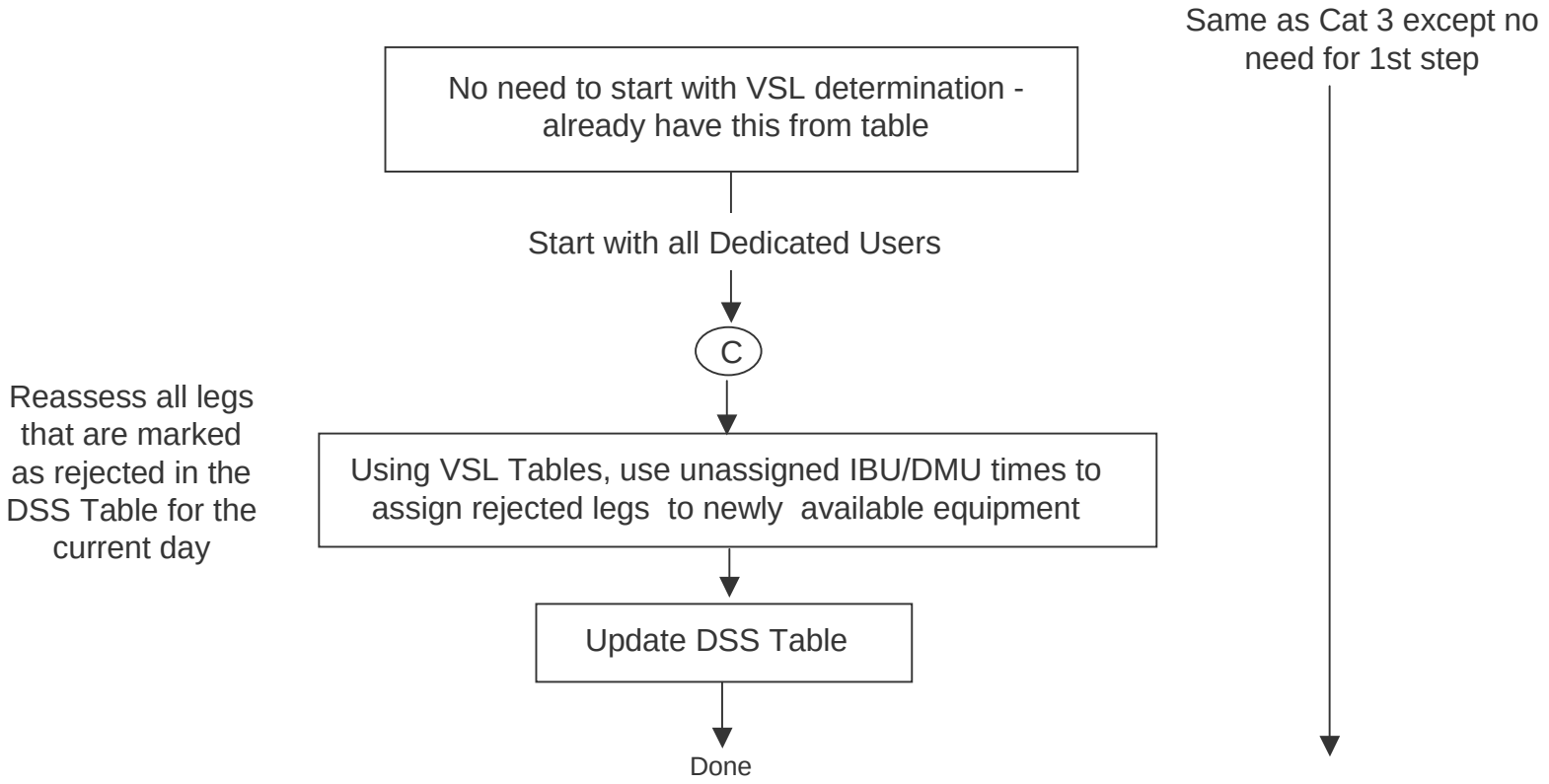


(Similar to Step 1 of Cat 2)

Reassess all legs that are marked as rejected in the DSS Table for the current day

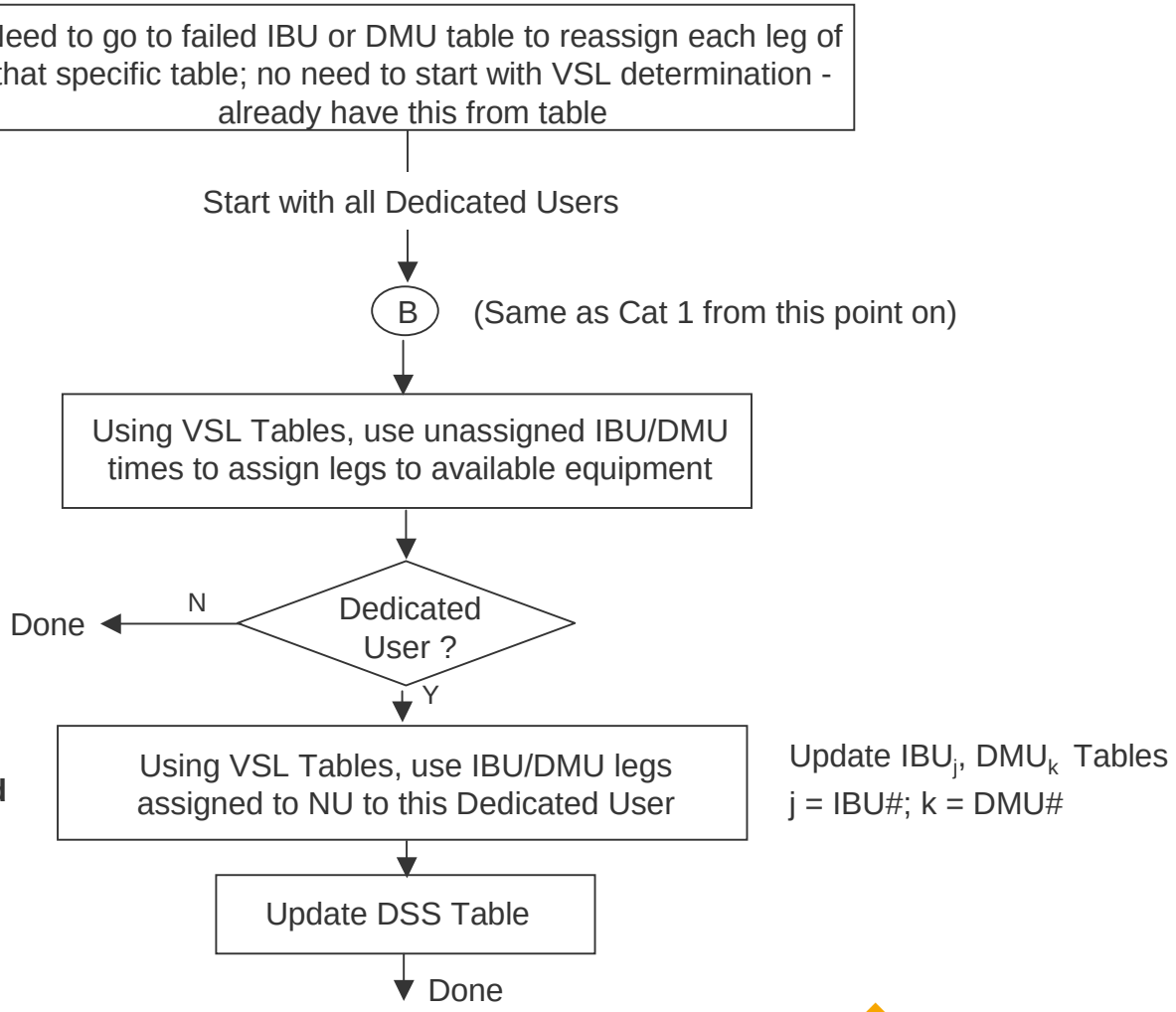
Emergency Replanning - Category 4

Newly Available IBU or DMU



Emergency Replanning - Category 5
Failed IBU or DMU

- **Reassign DUs first using available IBUs or DMUs and then those assigned to NUs**
- **Reassign NUs using available IBUs or DMUs (cannot bump anybody else)**

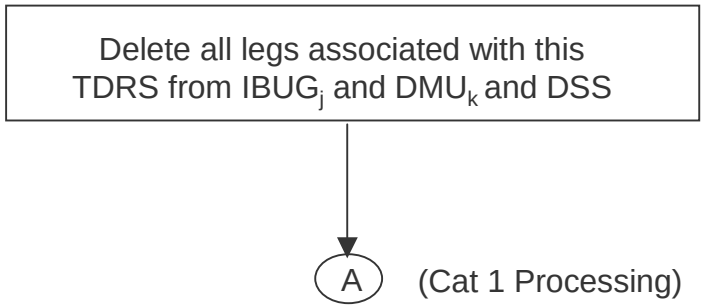


Emergency Replanning - Category 6
TDRS-IBUG Change

- **Only affects TDE and/or TDW assignments**
- **Assume that some Dedicated Users are affected**
- **There are numerous scenarios relating to how many IBUs at WSGT are affected**
  - A subset of IBUs (but still may need to reassign unaffected IBUs to accommodate DUs)
  - All IBUs (would have to do a total Replan for WSGT legs)
- **Recommend that a total replan is performed for all TDW and TDE legs**
  - This is the easiest approach
  - Replanning should be done in “minutes”
  - Same as Nominal Planning except that only those VSL_i ‘s associated with TDE and TDW are reassigned

Emergency Replanning - Category 7

New TDRS State Vector



Outline

Nominal (Re)Planning: Planning Prior to Service

Emergency Replanning: Planning During Service

Future Enhancements

Odd WSGT IBUG Optimization (Backup Only)

Future Enhancements
(Hooks in Place)

- **Priorities can be applied within the group of Dedicated users and non-dedicated users**
  - Order resource assignment process by this priority vs just DU and NU
- **Can declare that certain Non-dedicated users can not be bumped once service begins**
  - Have User Type column in the DSR run from 1 -3
- **IBUs and DMUs can be automatically cycled for 24x7 terrestrial users**
  - Use the 'continue' column of the DSR table
  - Note that IBUs and DMUs are automatically cycled for orbiting users even when they are 24x7
- **Can augment scheduling to recognize Formation Flyers without having separate service IDs but requires SWSI update as well to provide a field for this**
- **Can augment scheduling to recognize Users requesting multiple TDRSs without having separate service IDs but requires SWSI update as well to provide a field for this and also update in the Customer ICD**

Outline

<u>Nominal</u> (Re)Planning: Planning Prior to Service

<u>Emergency</u> Replanning: Planning During Service

Future Enhancements

Odd WSGT IBUG Optimization (Backup Only)

Handling of Odd IBUG (OIB) at WSGT
IBUG TDRS Identifier = 4

- **First IBUG table entry:**
  - 1,2,3 corresponds to TDZ, TDW, TDE and are fixed to a specific TDRS
  - 4 refers to Odd IBUG (denoted OIB) at WSGT varies between TDE or TDW - denote TDX
  - -1 to indicate not available
- **IBUG Quantity Notation**
  - NIBZ, NIBW, NIBE = number of IBUGs assigned to TDZ, TDW, TDE
  - NIBX = number of OIBs = 0 or 1
  - NIBT = NIBE + NIBW + NIBX = number of IBUGs at WSGT
  - NIBX = 0 (NIBT even) or 1 (NIBT odd)
  - $6 * NIBZ \geq ND$ (number of dedicated users)
  - $6 * (NIBE + NIBX) = 6 * (NIBW + NIBX) \geq ND$
- **Key Observations**
  - No problems when have an even # of IBUGs at WSGT
  - Assignment of the odd IBUG to either TDE or TDW is the issue here
  - 24x7 terrestrial users will be not be assigned to OIB because that would fix OIB to either TDE or TDW and make it too easy !
  - Services that have selected a specific TDRS will also not be assigned to the OIB

Key Algorithmic Considerations for the OIB

- **At any given time, one specific user will be assigned as the 'driver' for OIB**
- **There can not be more than one dedicated user assigned to the OIB (formation flyers are OK)**
  - This is a 'dedicated-user' constraint on the equipage that has been recognized (see previous slide)
- **Users will always first be assigned to 'even' IBUGs**
- **The first user requiring the OIB can either be a DU or NU but he will determine the OIB connectivity**
- **Whenever the first DU needs the OIB, he will automatically become the driver and 'bump' the ND as the driver here; and the ND will be rescheduled**
- **Note that the particular 'driver' user can change from time segment to time segment**

OIB IBUG Assignment Table, OIB

(IBUG Table and not IBU Table)

New Columns

OIB Table

Start Time	Finish Time	User Type	Service ID #	Leg ID #	TDW (2) or TDE (3)	Driver IBU (1-6)
T_{S3}	T_{F3}		XXXXXXX	ZZZ	TDW (=2)	5
T_{S2}	T_{F2}		XXXXXXX	ZZZ	TDW (=2)	3
T_{S1}	T_{F1}		XXXXXXX	ZZZ	TDE (=3)	6

- OIB Table is used to map allocations into IBU tables of those 6 IBUs that are in the OIB
- Note this table is also used by ICON to perform EMC I/F Switching on odd IBUG

OIB IBU[1] Assignment Table, IBU_j

J index corresponding to the 6 IBUs of the OIB

IBU[1] denotes an IBU table associated with the OIB

IBU[1] Table

New Column

Start Time	Finish Time	User Type	Service ID #	Leg ID #	TDW (2) or TDE (3)
4					
T_{S3}	T_{F3}		xxxxxxx	zzz	TDW (=2)
T_{S2}	T_{F2}		xxxxxxx	zzz	TDW (=2)
T_{S1}	T_{F1}		xxxxxxx	zzz	TDE (=3)

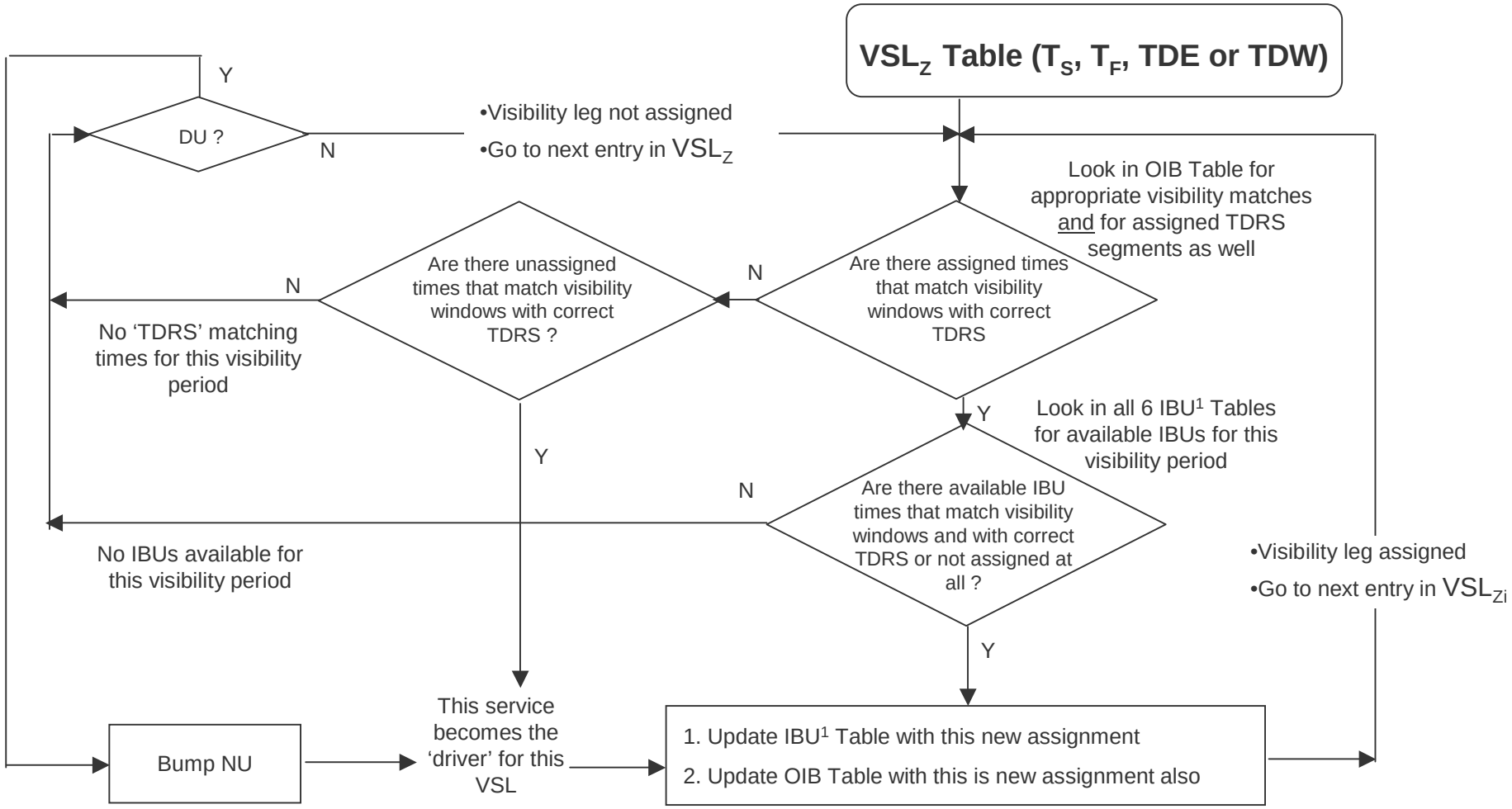
OIB Indicator: 4

Unlike 1-3 can vary between TDRSs so need another column indicating TDE or TDW

This column is completely determined by the corresponding column in the OIB Table

All 6 IBUs of the OIB have tables with this extra column

Generation of OIB, IBU Allocation Tables



Key Simplifying Assumptions
Multiple TDRSs per Node

- **There are no transitions required between TDRSS within a node**
  - Violates 'best look angle' requirement in the SRD
- **Transitions between nodes will be based on one specific TDRS within each node vs ultimately what TDRS within that node it eventually allocated**
  - Use 'west-most' TDRS at each node for transition time calculations
- **Users who request 'any TDRS'**
  - Assigned node solely based on best view angle using west-most TDRS at each node
  - Randomly assigned TDRS within each node
  - If no IBUs or DMUs available at the best-view node then this portion of the orbit is rejected (User would then request a specific node for this period to determine if there are resources available at the other node)
- **Users who request 'a specific TDRS'**
  - No visibility issue - use his requested TDRS
  - A Dedicated user would be assigned to his requested TDRS/IBU as a first priority (even before a another Dedicated user who had requested service first but for 'any' TDRS)
  - A Nondedicated user would have priority only based on his time of request; since the Scheduler randomly assigns IBUs among users he may be rejected due to lack of IBUs on his requested TDRS even though there may be spare IBUs on the other TDRS
- **Assume that a user cannot ask for a specific TDRS within a node and best-view TDRS as well**

Questions/Comments
Number of Services

- **How will the maximum number of simultaneous services for each Dedicated User be specified ?**
  - At time of initial setup of the user ?
  - Or via SWSI parameter ?

- **If he exceeds this number, what happens ?**
  - Do these "exceeded" services become nondedicated services ?
  - Do these nondedicated services have any priority over other nondedicated services ?
  - If there is a 'rejection' do we reject the last requested service and if so do we only reject on segments in which he exceeds the allocation ?

- **Can a Dedicated user request a nondedicated event ?**
  - How is this done ? Via a new SWSI parameter ?

- ***Even for a non-dedicated user, is there a max number of simultaneous events that the schedule needs to be aware and limit ?***